Working Document

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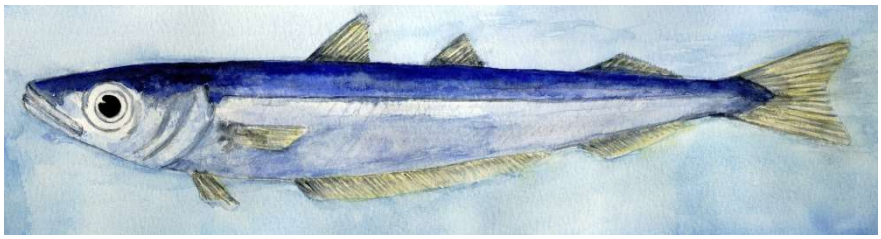

INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2019

Jan Arge Jacobsen[4*], Leon Smith[4*], Jens Arni Thomassen[4], Poul Vestergaard[4]
R/V Magnus Heinason

Bram Couperus[1*], Dirk Burggraaf[1], Felix Muller[7], Steven O'Connell[6], Thomas Pasterkamp[1], Kyle Sweeney[5], Dirk Tijssen[8]
R/V Tridens

Michael O'Malley[5*], Graham Johnston[5], Eugene Mullins[5], Ciaran O'Donnell[5*]
R/V Celtic Explorer

Åge Høines[2^*], Valantine Anthonypillai[2], Ørjan Sørensen[2], Ståle Kolbeinson[2], Justine Diaz[2]
M/S Kings Bay

Pablo Carrera[*99], Urbano Autón[*99], Ana [9]Antolínez[9]
R/V Miguel Oliver

1 Wageningen Marine Research, IJmuiden, The Netherlands
2 Institute of Marine Research, Bergen, Norway
3 PINRO, Murmansk, Russia
4 Faroe Marine Research Institute, Tórshavn, Faroe Islands
5 Marine Institute, Galway, Ireland
6 Marine Scotland Marine Laboratory, Aberdeen, Scotland, United Kingdom
7 Johann Heinrich von Thünen-Institut, Hamburg, Germany
8 Danish Institute for Fisheries Research, Denmark
9 Spanish Institute of Oceanography, SIO-IEO, Spain
* Participated in post cruise meeting,
^ Survey coordinator

Material and methods

Survey planning and Coordination

Coordination of the survey was initiated at the meeting of the Working Group on International Pelagic Surveys (WGIPS) in January 2019 and continued by correspondence until the start of the survey. During the survey effort was refined and adjusted by the survey coordinator (Norway) using real time observations. Participating vessels together with their effective survey periods are listed below:

Vessel	Institute	Survey period
Celtic Explorer	Marine Institute, Ireland	28/3 – 11/4
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	29/3 – 08/4
Tridens	Wageningen Marine Research, the Netherlands	19/3 – 02/4
Kings Bay	Institute of Marine Research, Norway	25/3 – 07/4
Miguel Oliver	Spanish Institute of Oceanography, Spain	18/3 – 21/3

The survey design was based on methods described in ICES Manual for International Pelagic Surveys (ICES, 2015). Overall weather conditions were mixed with periods of poor and good weather. All vessels experienced some downtime due to poor weather conditions. The entire survey was completed in 26 days, above the 21-day target threshold. However, the survey start was delayed by almost one week compared to 2018 and included additional effort by the Spanish survey in the Porcupine Sea bight.

Cruise tracks and survey strata are shown in Figure 1. Trawl stations for each participant vessel are shown in Figure 2 and CTD stations in Figure 3. All vessels worked in a northerly direction with the exception of the Faroes (Figure 4). Communication between vessels occurred daily via email to the coordinator (Norway) exchanging up to date information on blue whiting distribution, echograms, fleet activity and biological information.

Sampling equipment

Vessels employed a midwater trawl for biological sampling, the properties of which are given in Table 1. Acoustic equipment for data collection and processing are presented in Table 2. Survey abundance estimates are based on acoustic data collected from calibrated scientific echo sounders using an operating frequency of 38 kHz. All transducers were calibrated using a standardised sphere calibration (Demer et al. 2015) prior, during or directly after the survey. Acoustic settings by vessel are summarised in Table 2.

Biological sampling

All components of the trawl haul catch were sorted and weighed; fish and other taxa were identified to species level. The level of biological sampling by vessel is shown in Table 3.

Hydrographic sampling

Hydrographic sampling (vertical CTD casts) was carried out by each vessel at predetermined locations (Figure 3 and Table 3). Depth was capped at a maximum depth of 1000 m in open water. Not all pre-planned CTD stations were undertaken due to weather restrictions.

Plankton sampling

Plankton sampling by way of vertical WP2 casts were carried out by the Magnus Heinason (FO) to a depth of 200 m (Table 3).

Acoustic data processing

Echogram scrutinisation was carried out by experienced personnel, with the aid of trawl composition information. Post-processing software and procedures differed among the vessels;

On Celtic Explorer, acoustic data were backed up every 24 hrs and scrutinised using EchoView (V 9.0) post-processing software for the previous days work. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species (daylight only) and blue whiting.

On Magnus Heinason, acoustic data were scrutinised every 24 hrs on board using EchoView (V 9.0) post processing software. Data were partitioned into the following categories: plankton (<200 m depth layer), pearlside and mesopelagic species, blue whiting and krill (krill/mesopelagics). Partitioning of data into the above categories was based on trawl samples and acoustic characteristics on the echograms.

On Tridens, acoustic data were backed up continuously and scrutinised every 24 hrs using the Large Scale Survey System LSSS (2.5.0) post-processing software. Blue whiting were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

On Kings Bay, the acoustic recordings were scrutinized using LSSS (V. 2.5.0) once or twice per day. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species and blue whiting.

On Miguel Oliver, acoustic data were scrutinised every 24 hrs on board using EchoView (V 9.0) post processing software. Data were partitioned into the following categories: Müeller's pearlside, blue whiting and mesopelagic layer (mainly composed by krill and other mesopelagic fish species). Partitioning of data into the above categories was based on trawl samples and acoustic characteristics on the echograms.

Acoustic data analysis

Acoustic data were analysed using the StoX software package (V 2.7), as the standard adopted for WGIPS coordinated surveys. A description of StoX can be found here: http://www.imr.no/forskning_/prosjekter/stox/nb-no. Estimation of abundance from acoustic surveys with StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990). Baseline survey strata, established in 2017, were adjusted based on survey effort and observations in 2018 (Figure 1). The strata and transects used are shown in Figure 1 and 5. Length and weight data from trawl samples were equally weighted and applied across all transects within a given stratum (Figure 5).

Following the decisions made at the Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES, ICES 2012), the following target strength (TS)-to-fish length (L) relationship (Pedersen et al. 2011) is used:

$$TS = 20 \log10 (L) - 65.2$$

In StoX a super-individual table is produced where abundance is linked to population parameters including age, length, weight, sex, maturity etc. This table is used to split the total abundance estimate by any combination of population parameters. The StoX project folder for 2019 is available on request.

Estimate of relative sampling error

For the baseline run, StoX estimates the number of individuals by length group which are further grouped into population characteristics such as numbers at age and sex.

A total length distribution is calculated, by transect, using all the trawl stations assigned to the individual transects. Conversion from NASC (by transect) to mean density by length group by stratum uses the calculated length distribution and a standard target strength equation with user

defined parameters. Thereafter, the mean density by stratum is estimated by using a standard weighted mean function, where each transect density is weighted by transect distance. The number of individuals by stratum is given as the product of stratum area and area density.

The bootstrap procedure to estimate the coefficient of variance (RStoX V1.11) randomly replaces transects and trawl stations within a stratum on each successive run. The output of all the runs is stored in a RData-file, which is used to calculate the relative sampling error.

Results

Distribution of blue whiting

In total 7,610 nmi (nautical miles) of survey transects were completed across six strata, relating to an overall geographical coverage of 121,397 nmi² (Figure 1, Tables 3). The acoustic sampling effort area increased in 2019 to include the Porcupine sea bight area. Otherwise area coverage was comparable to 2018 (Table 7). The stock was considered well contained within core and peripheral abundance areas (Rockall Bank and south Porcupine Bank). The distribution of blue whiting as observed during the survey is shown in Figures 6 and 7.

The bulk of the stock in 2019 was located in the 3 strata that covers the shelf edge area (Strata 1, 2 and 3) accounting for 95% of total biomass (Table 4). The Rockall Trough area alone (strata 3) accounted for 61% of the overall survey estimate; this is at a similar level to the two previous years. The Porcupine Bank (strata 2) increased by 57% and contained 21% of the stock compared to 13% in 2018. The three strata outside the core shelf edge area (stratum 4, 5, and 6) collectively decreased from around 12% in 2018 to 5% in 2019 (Table 4). The Rockall and Hatton Bank area (strata 5) contributed just 0.7% of the overall biomass of blue whiting in 2019, down from 4% in 2018. A decrease in salinity and temperature observed in 2017 persists through 2018 and 2019 (see next section).

The two northernmost strata (South Faroes (strata 4) and Shetland Channel (strata 6) accounted for the remaining 4.1% of the biomass (Table 4).

The highest s_A value (98,698 m²/nmi² - sampling unit: one nautical mile) observed in the survey in 2019 was recorded by FV *Kings Bay* on the northern slope of Porcupine Bank in strata 2 (Figure 8a). An example of a typical high density layer of blue whiting observed in the Rockall Trough strata is shown in Figure 8b. A weak layer of blue whiting from the Rockall Bank strata is shown in Figure 8c. Juvenile blue whiting were mainly observed in the northern stratum (South Faroes and Faroe – Shetland Channel) and an example echogram is shown in Figure 8d. High density blue whiting registrations were observed in the Porcupine Sea bight by the RV *Miguel Oliver* (Figure 8e & 8f).

The vertical distribution of blue whiting observed in 2019 did not extend deeper than 750 m as observed in 2018. However, schools in the Porcupine sea bight were observed down to a depth of 600 m.

Stock size

The estimated total biomass of blue whiting for the 2019 international survey was 4.2 million tonnes, representing an abundance of 36.9×10^9 individuals (Table 4). Spawning stock was estimated at 4.17 million tonnes and 35.8×10^9 individuals (Table 5).

Stock composition

Individuals of ages 1 to 13 years were observed during the survey.

The main contribution (82%) to the spawning stock biomass were the age groups 4, 5 and 6 with the five year olds (2014 year-class) being most abundant (47%), followed by the 2015 year-class (24%) and 2013 year-class (11%) (Table 5).

The highest mean weights of blue whiting were caught in the northern part of the Rockall Trough stratum 3 (Figures 9 and 10). Highest mean weight in 2019 was in strata 3 representing 121g.

Five year olds (the 2014 year-class) were dominant in all strata with the exception of strata 4 (south Faroes) and strata 6 (Faroe/Shetland Channel), where 1 year olds ranked highest (Figure 12). The proportion of 1 and 2-year-old fish was low in the total estimate in 2019 (Figure 13).

An uncertainty estimate at age based on a comparison of the abundance estimates was calculated for IBWSS for years 2017, 2018 and 2019 using StoX (Figure 11). By comparing the estimates of young year classes from 2017 to 2019 it appears that good cohort tracking is achieved in the survey for some year classes. For example, the relative abundance of two year olds in 2016 (2014-year class) was high; the strong abundance of this cohort is also seen in 2017 as three year olds, in 2018 as four year olds, and in 2019 as five year olds. Similarly, the 2015 year-class were picked up as two year olds in 2017, and subsequently the three and four year olds in 2018 and 2019 respectively are relatively strong. The CV of the abundant age groups 3 to 6 was below 0.25 in 2019 (Figure 11).

The CV of the total estimate of both biomass and abundance were 0.17, which is higher than last year (0.125) and slightly higher than the years before when the CV varied around 0.16.

The survey time series (2004-2019) of TSN and TSB are presented in Figures 14 and 15 respectively and Table 6.

Hydrography

A total of 118 CTD casts were undertaken over the course of the survey (Table 1). Horizontal plots of temperature and salinity at depths of 50 m, 100 m, 200 m and 500 m as derived from vertical CTD casts are displayed in Figures 16-19 respectively. A decrease in salinity and temperature observed in 2017 persists through 2018 and 2019. This is thought to limit the western extent of the blue whiting spawning distribution on the Rockall and Hatton Bank areas (Hátún *et al.* 2009).

Concluding remarks

Main results

- Weather conditions were mixed with both good and bad periods. All vessels experienced poor weather conditions at some point during the survey, resulting in slower transect speeds.
- The total area surveyed was comparable but lower than in 2018. Corresponding acoustic sampling effort (transect miles) increased. Reduced area coverage can be accounted by the lack of blue whiting in western peripheral areas (stratum 5- Rockall). Acoustic sampling increased due to the presence of the RV *Miguel Oliver* and her coverage of the Porcupine sea bight. Coverage in the sea bight can be considered a new extension of the total survey area and is necessary to contain the stock in its southern boundary.
- Overall, biological sampling saw an increased number of measured fish but a lower number of aged individuals compared to 2018.
- The International Blue Whiting Spawning Stock Survey 2019 shows an increase in total stock biomass of 4% with a corresponding decrease in total abundance of 9% when compared to the 2018 estimate.
- The survey was carried out over 26 days, above the 21-day time window target. These additional days can be accounted for the by the delayed start of the RV *Celtic Explorer* compared to previous years.
- Estimated uncertainty around the total stock biomass was higher than last year, CV=0.17 compared to 0.13.
- The stock biomass within the survey area was dominated by 4, 5 and 6-year-old fish contributing 82% of total stock biomass.
- There was no evidence of blue whiting below 750 m
- Immature fish (1-year-old) represent 0.7% of the TSB and 2.9% of TSN.

Interpretation of the results

- The group considers the 2019 estimate of abundance as robust. Good stock containment was achieved for both core and peripheral strata. Sampling effort (biological and acoustic), was comparable to previous years.
- Total stock biomass observed in 2019 is the highest in the overall time series (2004-present). Representing an increase in TSB of 4% compared to 2018 (4.0 mt and 4.2 mt respectively). The 2014-year class (5 year old fish) accounts for approximately 46% of the TSB and almost 2 million tons. This year class is the largest observed in the survey time series.
- The bulk of SSB was distributed from the northern edge of the Porcupine Bank and continued northwards through the Rockall Trough and up to the Hebrides.
- The Northern migratory stock and the Porcupine sea bight; Spatio-temporal survey data and biological data from trawl hauls (RV *Tridens* and RV *Miguel Oliver*) were comparable in terms of length cohorts. The eastward extension of the survey area is necessary to contain the northern stock. Comparative analysis of age readings is required.

Recommendations

- The group recommends that coverage in the western Rockall/Hatton Bank (stratum 5) should be carried out based on real time observations. That is, effort should not be expended where no aggregations are evident and transects are terminated when no blue whiting is

observed for 15 nmi consistent ‘clear water’ miles. This applies to peripheral regions to the west of the Rockall and Hatton Bank areas.

- To facilitate the process of calculating global biomass the group requires that all data be made available at least 72 hours in advance of the meeting start date.
- The group recommends that the process of producing output reporting tables, figures and maps from StoX outputs files is standardised through scripting routines and developed by WGIPS for wider use.
- To facilitate the above process, we request that StoX developers look into the possibility of fixing the format of output tables of biomass and abundance to aid this process. Currently zero values in biomass and abundance tables (age and lengths) are omitted.
- Current XML file formats generated from ICES or PGNAPES data repositories are not cross compatible for combined use in StoX due to differences in formatting. As the group diverges from using PGNAPES as the sole data repository to using the ICES acoustic database members need to be clear during the planning phase on which repository they intend to use going forward. This issue requires attention during WGIPS in 2020 so as not to disrupt the process of global abundance estimation in 2020.
- It is recommended that all participants produce files types in both ICES and PGNAPES file formats for the 2020 post cruise meeting to facilitate cross compatibility testing within StoX.

Achievements

- The Porcupine sea bight was covered synoptically, in close temporal progression by two survey vessels.
- Acoustic sampling effort (track miles), trawling effort and biological metrics of blue whiting were comparable to 2018.

References

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Table 1. Country and vessel specific details, IBWSS March-April 2019.

	Celtic Explorer	Magnus Heinason	Tridens	Kings Bay	Miguel Oliver
Trawl dimensions					
Circumference (m)	768	640	860	832	752
Vertical opening (m)	50	42-45	30-70	45	30
Mesh size in codend (mm)	20	40	40	40	20
Typical towing speed (kn)	3.5-4.0	3.2-3.6	3.5-4.0	3.5-4.0	3.5-4.0
Plankton sampling	-	16	-	-	
Sampling net	-	WP2 plankton net	-	-	
Standard sampling depth (m)	-	200	-	-	
Hydrographic sampling					
CTD Unit	SBE911	SBE911	SBE911	SBE25	SBE25
Standard sampling depth (m)	1000	1000	1000	900	520

Table 2. Acoustic instruments and settings for the primary frequency, IBWSS March-April 2019.

	Celtic Explorer	Magnus Heinason	Tridens	Kings Bay	Miguel Oliver
Echo sounder	Simrad EK 60	Simrad EK60	Simrad EK 60	Simrad EK 80	Simrad EK 60
Frequency (kHz)	**38**, 18, 120, 200	**38**, 200	18, **38**, 70, 120, 200, 333	18, **38**, 70	**38**, 18, 70, 120, 200
Primary transducer	ES 38B	ES 38B	ES 38B	ES 38B	ES 38B
Transducer installation	Drop keel	Hull	Drop keel	Drop keel	Hull
Transducer depth (m)	8.7	3	8	8.5	6.5
Upper integration limit (m)	15	7	15	15	15
Absorption coeff. (dB/km)	9.9	10.1	9.5	9.59	9.2
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	2.43	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	23	21.9
2-way beam angle (dB)	-20.6	-20.8	-20.6	-20.7	-20.6
Sv Transducer gain (dB)					
Ts Transducer gain (dB)	25.85	25.64	26.52	24.06	24.68
s_A correction (dB)	-0.64	-0.66	-0.76	0.008	-0.54
3 dB beam width (dg)					
alongship:	6.87	7.02	6.79	7.0	6.90
athw. ship:	6.91	7.00	6.81	7.0	7.10
Maximum range (m)	750	750	750	750	1000
Post processing software	Echoview	Echoview	LSSS	LSSS	Echoview

Table 3. Survey effort by vessel, IBWSS March-April 2019.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Plankton sampling WP2-net	Aged fish	Length-measured fish
Celtic Explorer	28/3-11/4	2282	7	24	-	350	3001
Magnus Heinason	29/3-8/4	1400	6	19	17	300	668
Kings Bay	25/3- 7/4	2185	11	27	-	330	1,091
Tridens	19/3-2/4	1473	10	28	-	798	800
Miguel Oliver	18/3-21/3	270	4	20	-	160	668
Total	28/3-11/4	7610	38	118	17	1938	6228

Table 4. Abundance and biomass estimates of blue whiting by strata in 2019 and 2018. IBWSS March-April 2019.

Strata	Name	2019				2018				Difference 2019-2018	
		TSB (10^3 t)	TSN (10^9)	% TSB	% TSN	TSB (10^3 t)	TSN (10^9)	% TSB	% TSN	TSB	TSN
1	Porcupine Bank	870	8,350	20.7	22.6	534	5,519	13.2	13.6	57%	66%
2	N Porcupine Bank	572	5,692	13.6	15.4	521	5,599	12.9	13.8	6%	12%
3	Rockall Trough	2,555	21,116	60.9	57.2	2,475	24,708	61.4	60.9	-1%	-6%
4	South Faroes	125	1,039	3.0	2.8	164	1,604	4.1	4.0	-27%	-29%
5	Rockall Bank	29	272	0.7	0.7	179	1,835	4.4	4.5	-85%	-84%
6	Faroe/Shetland Ch.	47	448	1.1	1.2	162	1,336	4.0	3.3	-72%	-63%
	Total	4,198	36,918	100	100	4,035	40,602	100	100	4%	-9%

Table 5. Survey stock estimate of blue whiting, IBWSS March-April 2019.

					Age in years (year class)						Number	Biomass	Mean	Prop
Length	1	2	3	4	5	6	7	8	9	10+			weight	Mature
(cm)	2018	2017	2016	2015	2014	2013	2012	2011	2010		(10^6)	(10^6 kg)	(g)	
16-17	11										11	0.3	28	0
17-18	50										50	1.6	31	0
18-19	184										184	6.1	33	50
19-20	233										233	8.2	35	16
20-21	291										291	13.5	46	23
21-22	173										173	8.8	51	21
22-23	82	19	4								104	6.5	62	46
23-24	81	89	2								172	11.6	67	59
24-25	35	380	113								528	38.3	73	95
25-26		475	467	281	638	101					1,962	164.0	84	100
26-27		146	948	2,125	2,069	209					5,497	506.0	92	100
27-28		43	1,038	2,589	3,514	574					7,759	787.1	101	100
28-29		14	421	2,348	4,765	406	31	7			7,991	889.8	111	100
29-30		3	182	921	2,853	666	28		7		4,660	579.3	124	100
30-31			150	862	1,651	669	103	37			3,473	480.0	138	100
31-32				380	758	257	170				1,564	244.7	156	100
32-33			144	63	442	79	40	195		18	982	181.9	185	100
33-34				20	97	336	47	114			614	113.2	184	100
34-35					109	86	26	42		5	269	57.5	214	100
35-36					68	2		65		2	137	32.6	238	100
36-37							15		74	12	101	21.8	215	100
37-38						22		41	11	6	80	21.9	274	100
38-39					14	18		13			46	10.0	218	100
39-40							24				24	7.7	316	100
40-41											0		-	100
41-42						8					8	3.1	372	100
43-44									6		6	2.4	397	100
TSN(mill)	1,129	1,169	3,468	9,590	16,979	3,434	484	513	99	144	36,918			
TSB(1000 t)	51.7	94.4	358.2	1,025.1	1,962.1	463.3	81.4	131.4	20.6	38.2	4,197.6			
Mean length(cm	20.1	25.0	27.1	27.9	28.4	29.5	31.7	33.4	36.2					
Mean weight(g)	46	81	103	107	116	135	168	256	209					
% Mature	8	99	98	100	100	100	100	100	100	100				
SSB (1000kg)	4.3	93.4	349.5	1024.5	1961.4	463.3	81.4	131.4	20.6	38.2	4168.0			
SSN (mill)	93	1156	3384	9584	16973	3434	484	513	99	144	35862.1			

Table 6. Time series of StoX abundance estimates of blue whiting (millions) by age in the IBWSS. Total biomass in last column (1000 t).

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	TSB
2004	1,097	5,538	13,062	15,134	5,119	1,086	994	593	164		3,505
2005	2,129	1,413	5,601	7,780	8,500	2,925	632	280	129	23	2,513
2006	2,512	2,222	10,858	11,677	4,713	2,717	923	352	198	31	3,512
2007	468	706	5,241	11,244	8,437	3,155	1,110	456	123	58	3,274
2008	337	523	1,451	6,642	6,722	3,869	1,715	1,028	269	284	2,639
2009	275	329	360	1,292	3,739	3,457	1,636	587	250	162	1,599
2010*											
2011	312	1,361	1,135	930	1,043	1,712	2,170	2,422	1,298	250	1,826
2012	1,141	1,818	6,464	1,022	596	1,420	2,231	1,785	1,256	1,022	2,355
2013	586	1,346	6,183	7,197	2,933	1,280	1,306	1,396	927	1,670	3,107
2014	4,183	1,491	5,239	8,420	10,202	2,754	772	577	899	1,585	3,337
2015	3,255	4,565	1,888	3,630	1,792	465	173	108	206	247	1,403
2016	2,745	7,893	10,164	6,274	4,687	1,539	413	133	235	256	2,873
2017	275	2,180	15,939	10,196	3,621	1,711	900	75	66	144	3,135
2018	836	628	6,615	21,490	7,692	2,187	755	188	72	144	4,035
2019	1,129	1,169	3,468	9,590	16,979	3,434	484	513	99	144	4,198

*Survey discarded.

Table 7. Survey effort in the IBWSS.

Survey effort	Survey area (nmi²)	Transect n. miles (nmi)	Trawls	CTDs	Plankton	Bio sampling (WHB)	
						Measured	Aged
2004	149 000		76	196			
2005	172 000	12 385	111	248	-	29 935	4 623
2006	170 000	10 393	95	201	-	7 211	2 731
2007	135 000	6 455	52	92		5 367	2 037
2008	127 000	9 173	68	161	-	10 045	3 636
2009	133 900	9 798	78	160	-	11 460	3 265
2010	109 320	9 015	62	174	-	8 057	2 617
2011	68 851	6 470	52	140	16	3 810	1 794
2012	88 746	8 629	69	150	47	8 597	3 194
2013	87 895	7 456	44	130	21	7 044	3 004
2014	125 319	8 231	52	167	59	7 728	3 292
2015	123 840	7 436	48	139	39	8 037	2 423
2016*	134 429	6 257	45	110	47	5 390	2 441
2017	135 085	6 105	46	100	33	5 269	2 477
2018	128, 030	7 296	49	101	45	5 315	2 619
2019	121, 397	7, 610	38	118	17	6 228	1 938

* End of Russian participation.

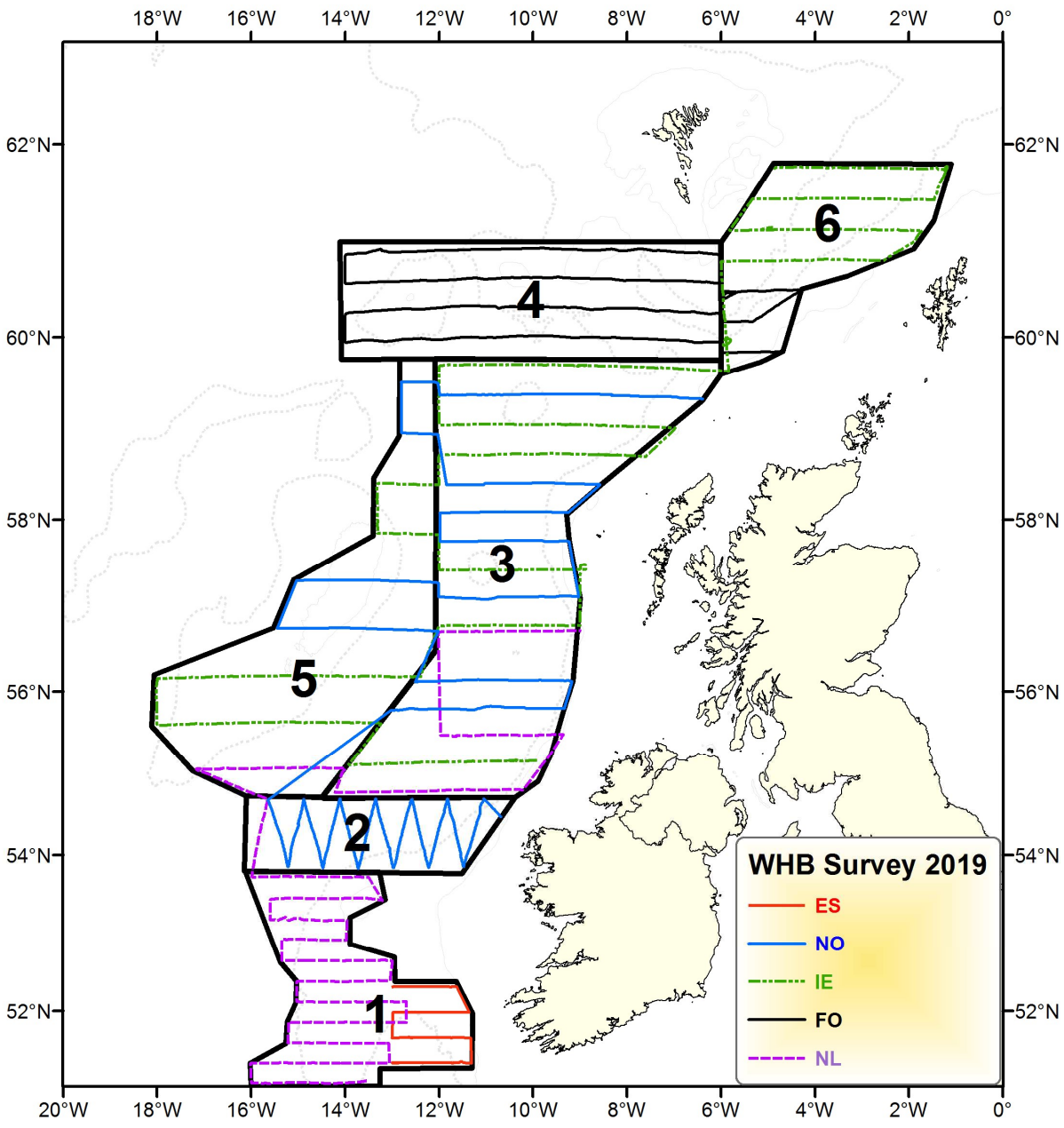


Figure 1. Strata and cruise tracks for the individual vessels (country) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019.

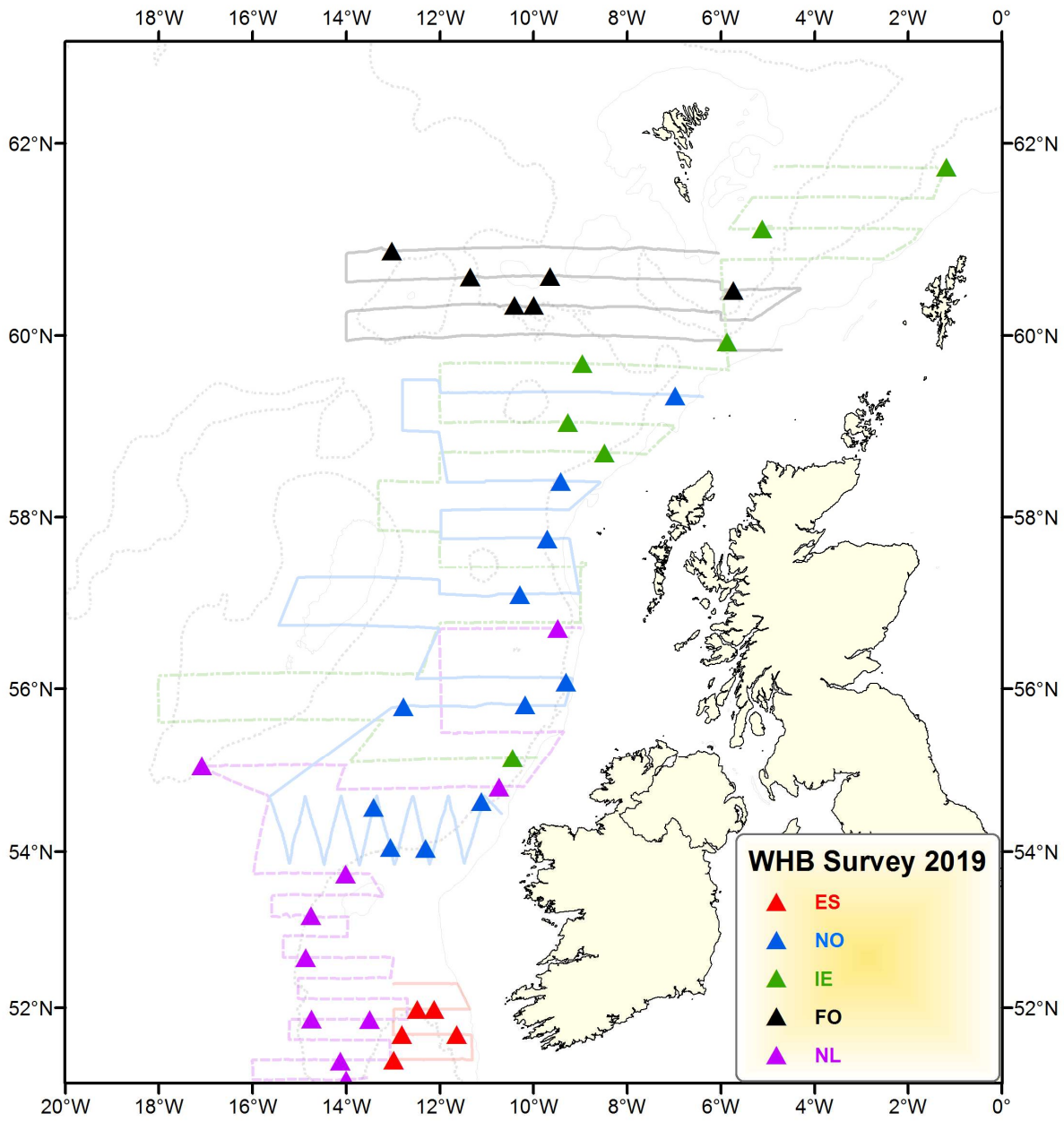


Figure 2. Vessel cruise tracks and trawl stations of the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019. IE: Ireland (RV *Celtic Explorer*); FO: Faroe Islands (RV *Magnus Heinason*); NL: Netherlands (RV *Tridens*); NO: Norway (FV *Kings Bay*); ES: Spain (RV *Miguel Oliver*).

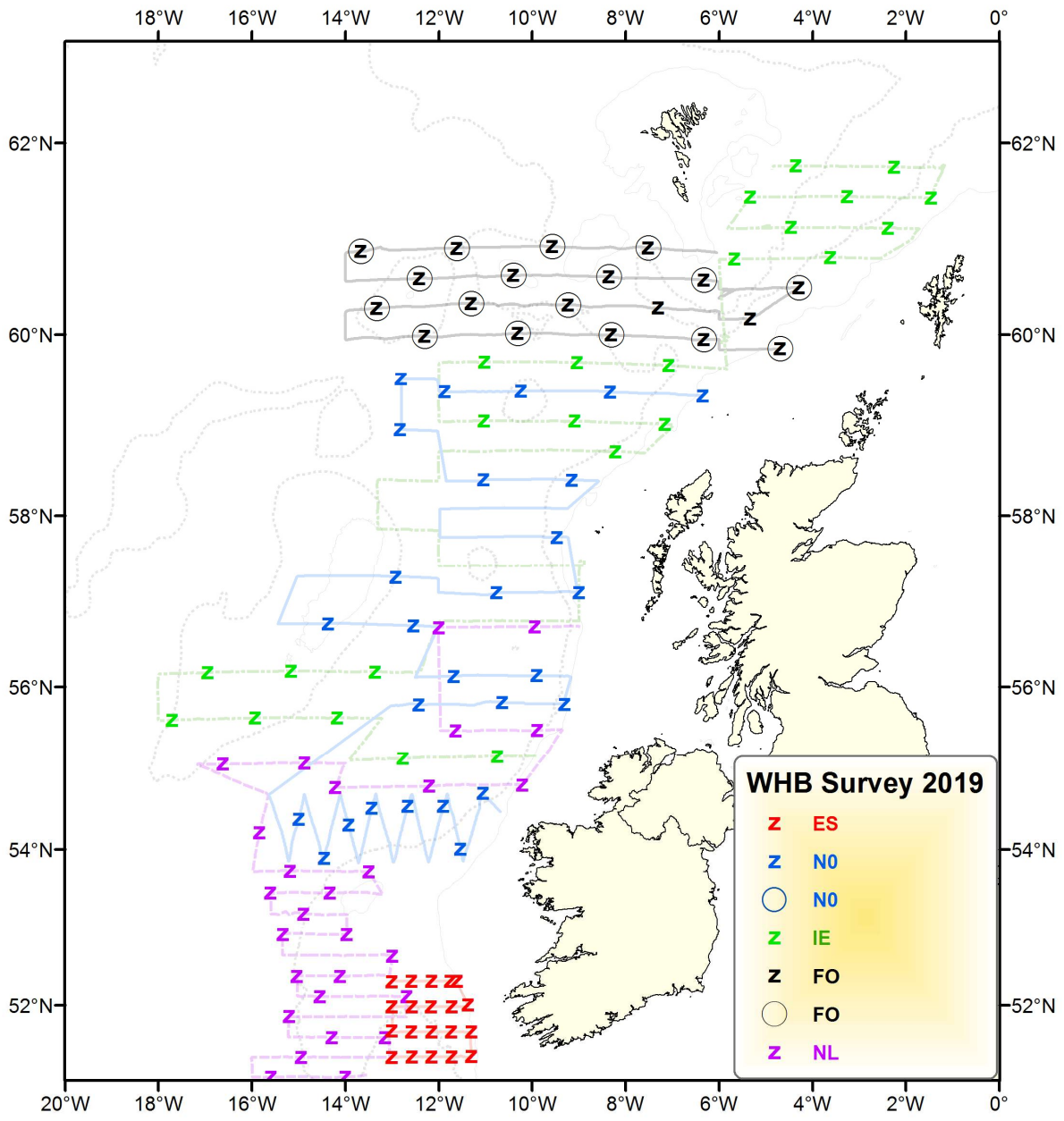


Figure 3. Vessel cruise tracks with hydrographic CTD stations (z) and WP2 plankton net samples (circles) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019. Colour coded by vessel.

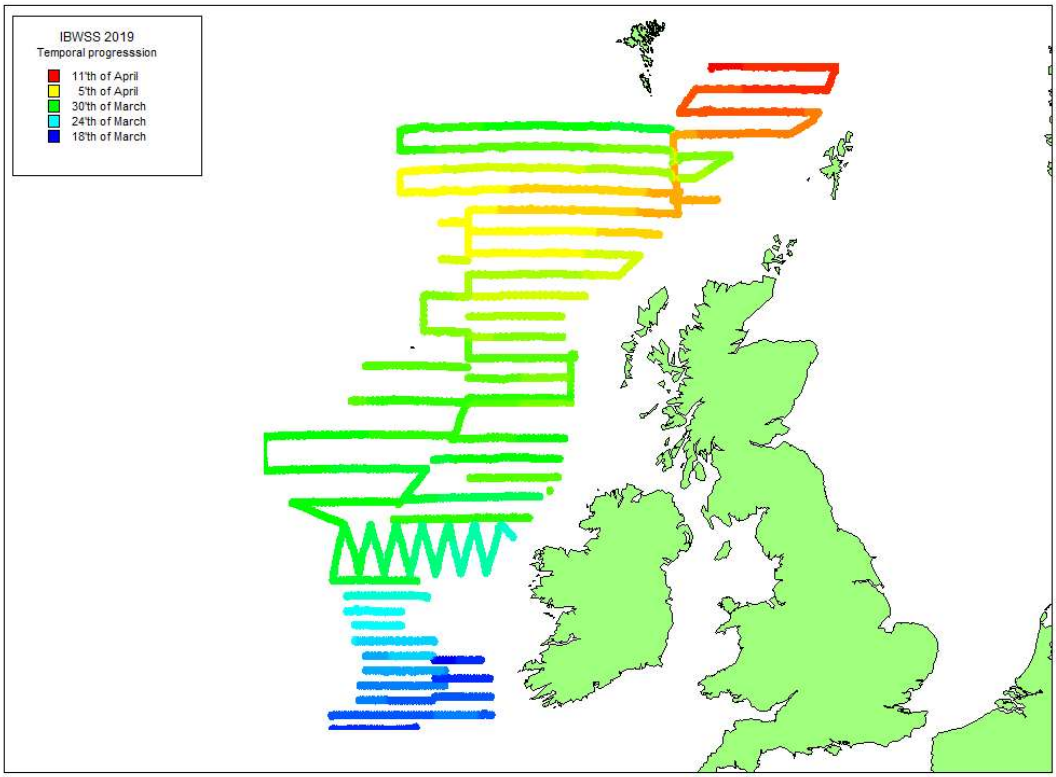


Figure 4. Temporal progression for the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019.

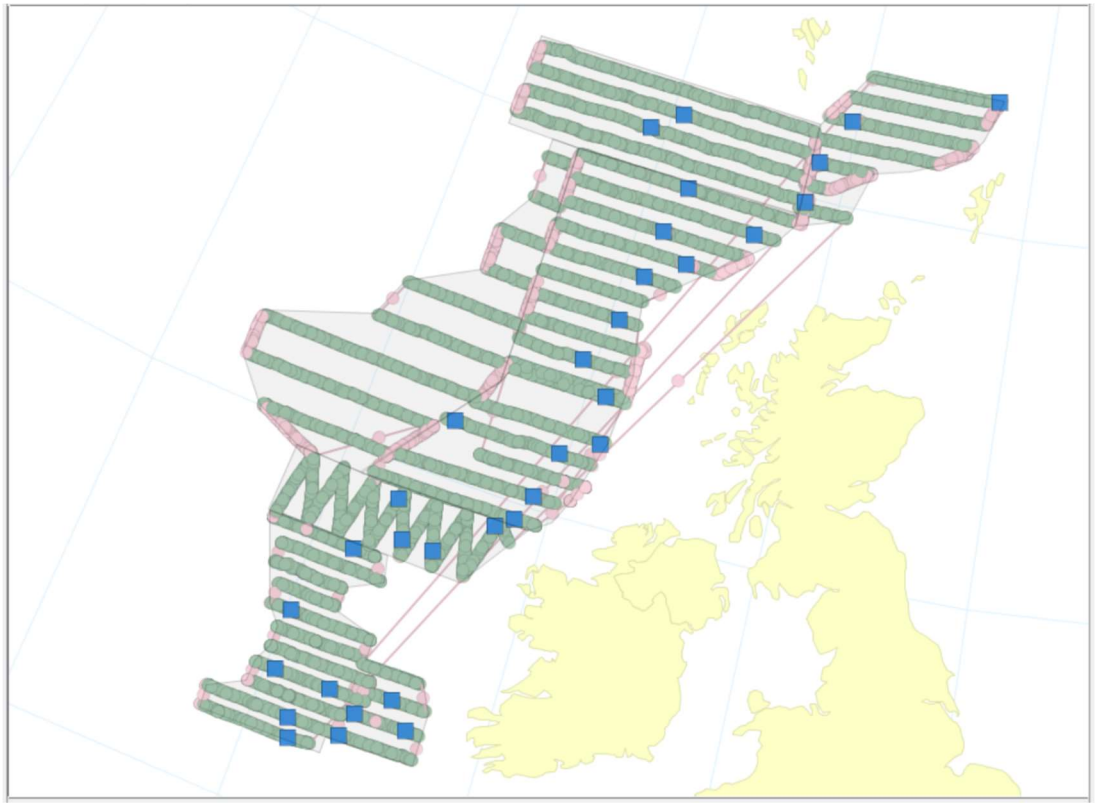


Figure 5. Tagged acoustic transects (green circles) with associated trawl stations containing blue whiting (blue squares) used in the StoX abundance estimation. IBWSS March-April 2019.

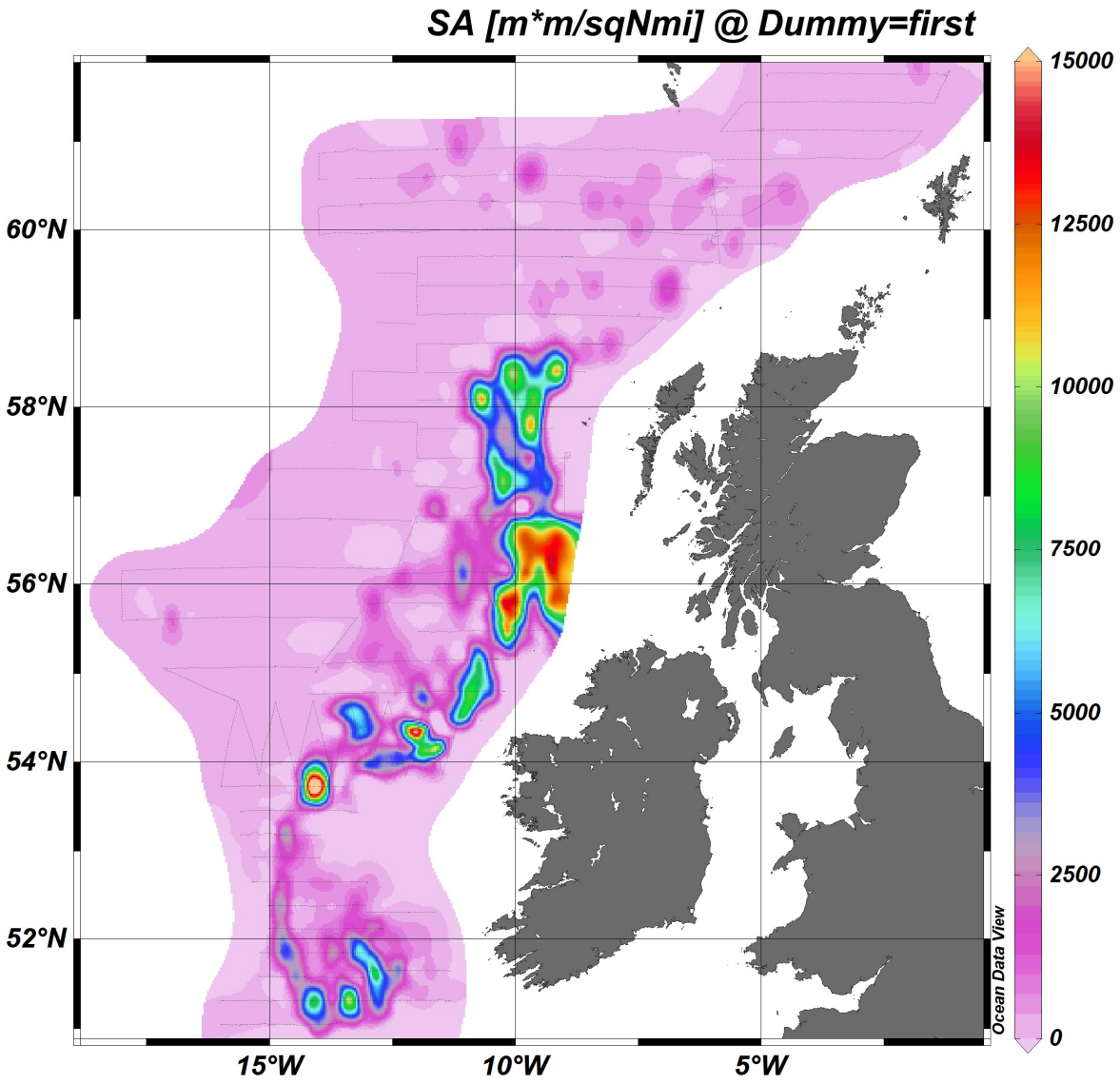


Figure 6. Map of acoustic density (s_A m^2/nmi^2) of blue whiting during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019.

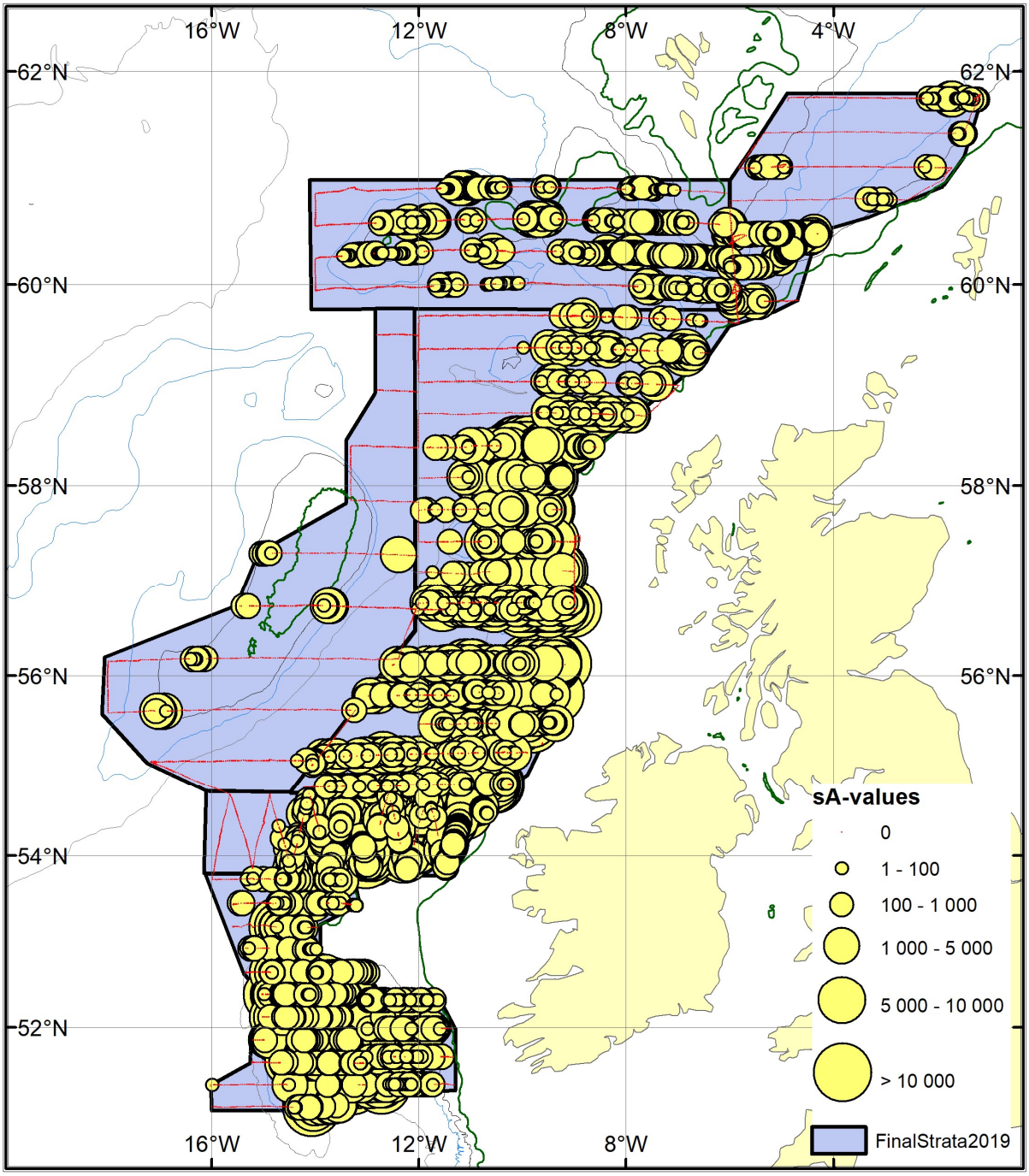
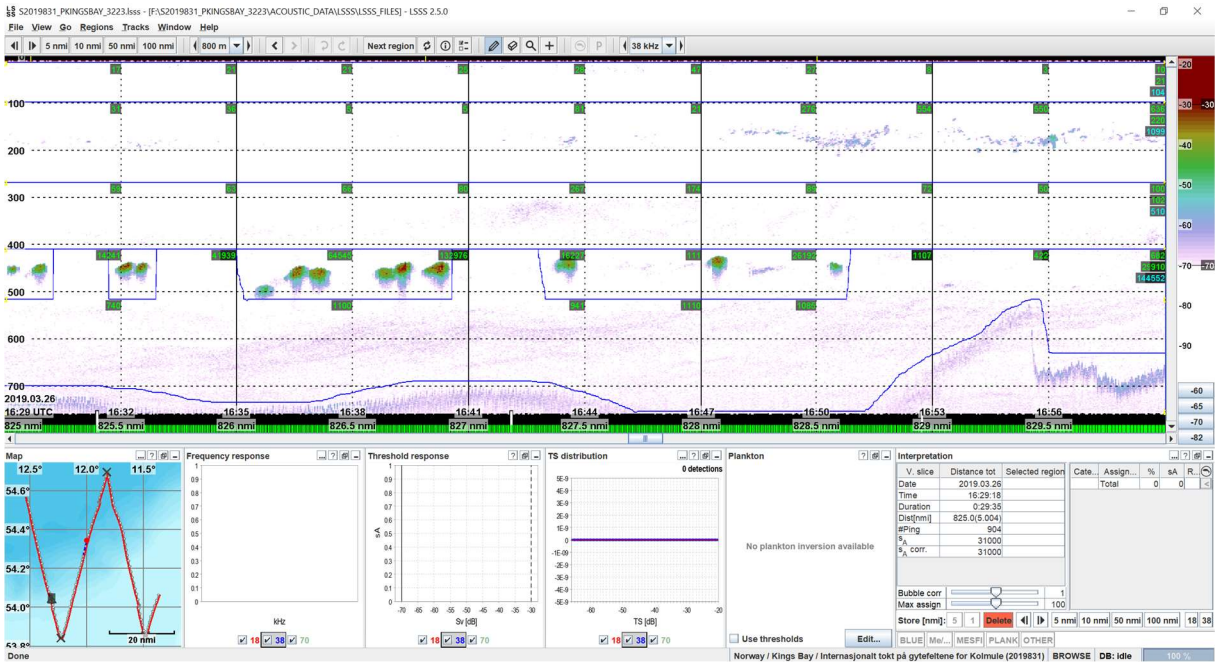
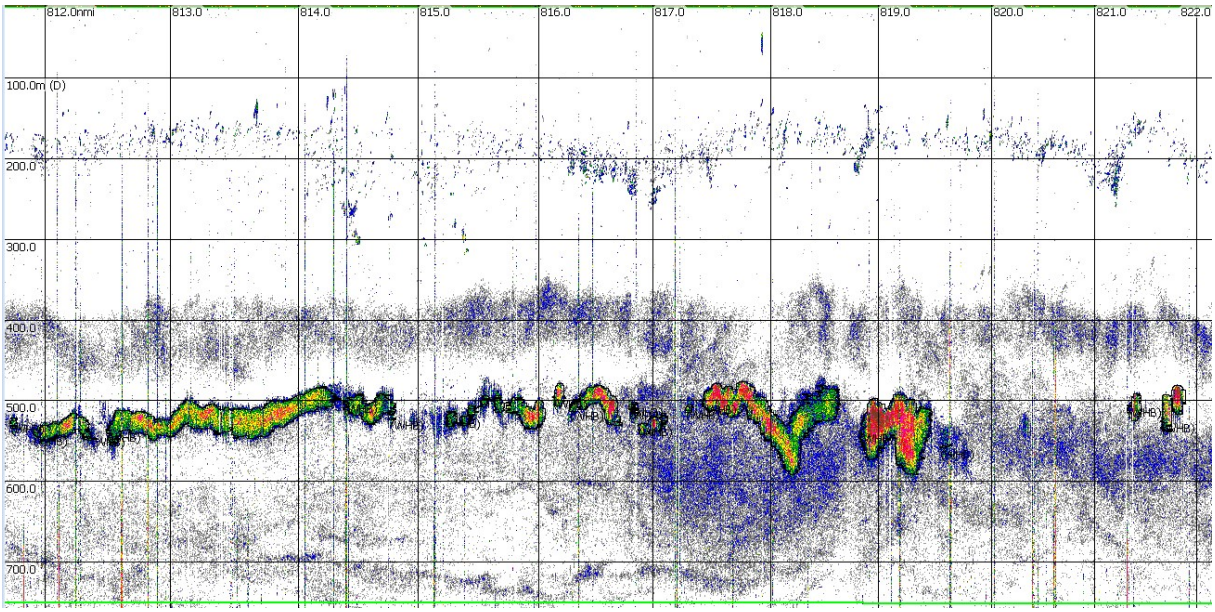


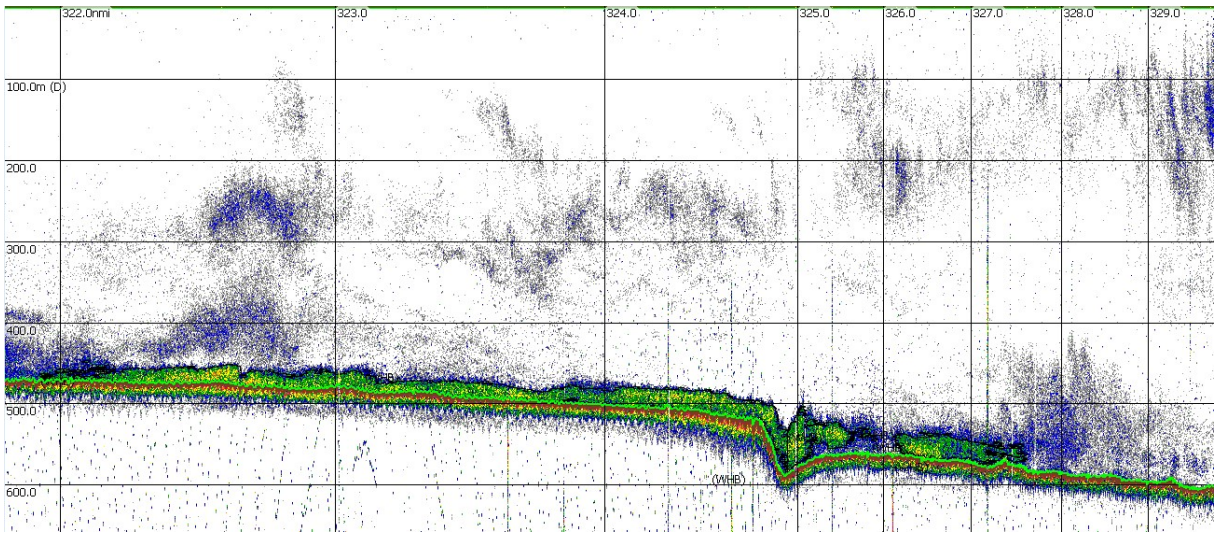
Figure 7. Map of acoustic density (s_A m^2/nmi^2) of blue whiting by 1 nmi (circle scaled by acoustic density). IBWSS March-April 2019.



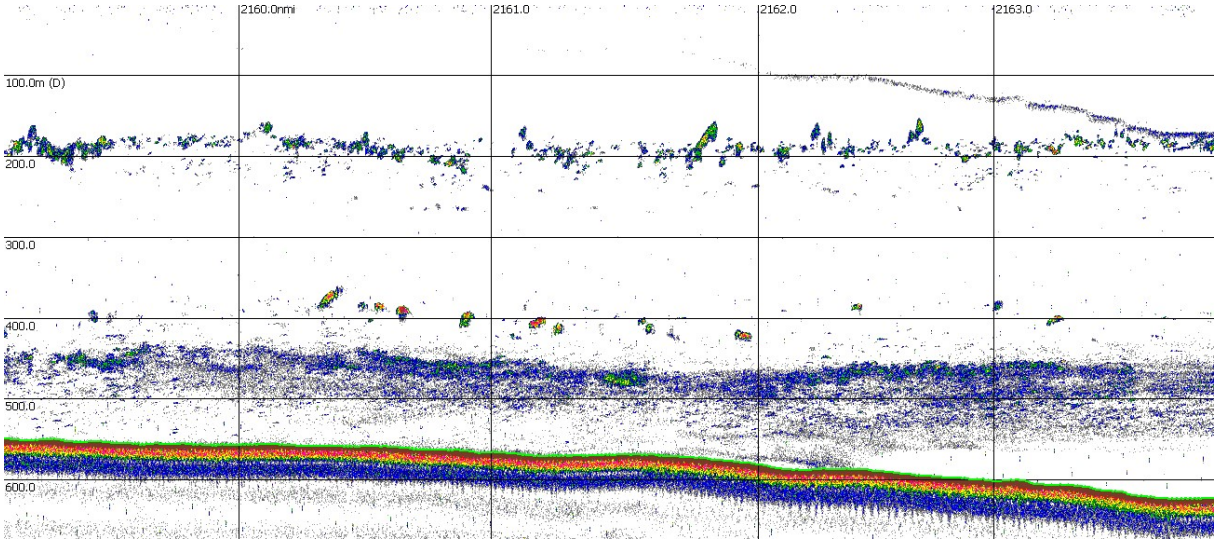
a) High density blue whiting registrations recorded on western Porcupine Bank area (strata 2) FV *Kings Bay*, Norway.



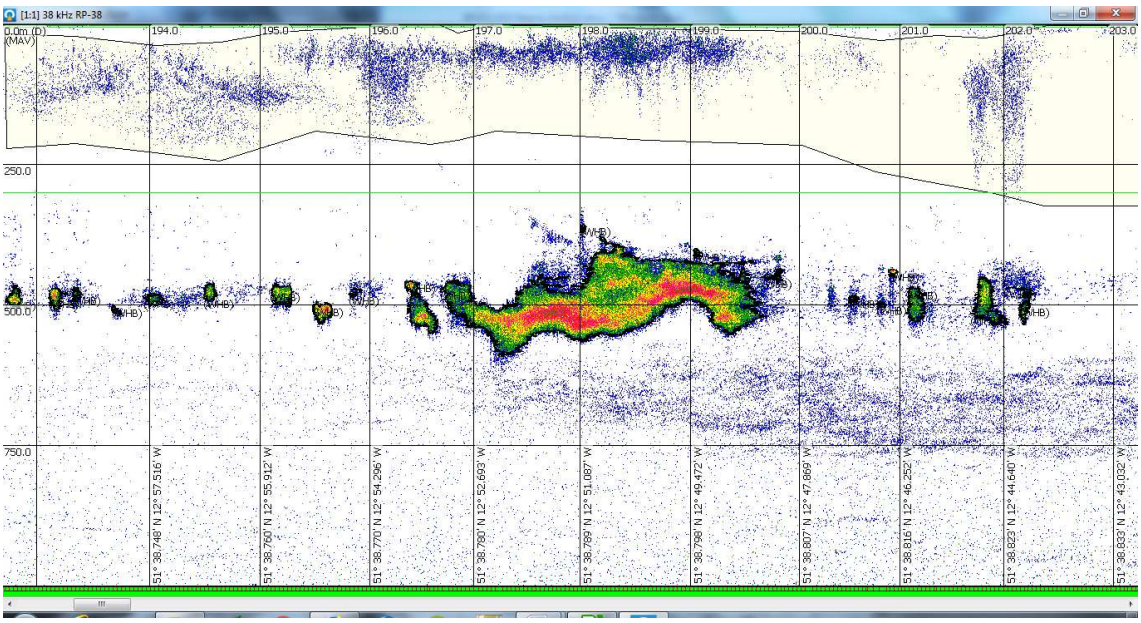
b) High density blue whiting layer per 1 nmi log interval at 500- 600 m recorded by the RV *Celtic Explorer* in the Rockall Trough area (strata 3).



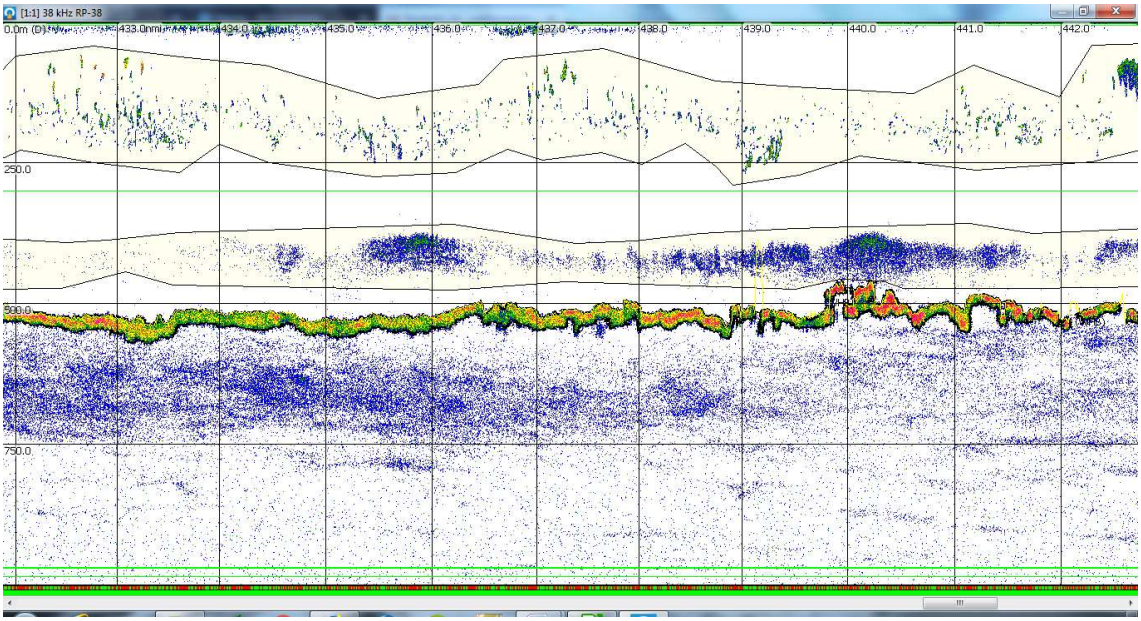
c) Low density blue whiting layer per 1nmi log interval close to the bottom at 450 – 550 m recorded by the RV *Celtic Explorer* in the Rockall Bank area (strata 5).



d) Juvenile and adult blue whiting marks per 1nmi log interval at 400 m depth. A layer of mesopelagic fish is also evident at 150 – 200 m. Recorded by the RV *Celtic Explorer* in the Faroe – Shetland channel area (strata 6).



e) High density blue whiting schools-like at 500- 600 m recorded by the RV *Miguel Oliver* at night in the Porcupine Sea bight area (stratum 7).



f). High density day time blue whiting layer at 500- 600m recorded by the RV *Miguel Oliver* the Porcupine Sea bight area (stratum 7).

Figure 8. Echograms of interest encountered during the IBWSS, March-April 2019. Vertical banding represents 1 nmi acoustic sampling intervals (EDSU), vertical binning at 50 m intervals. All echograms presented at 38 kHz.

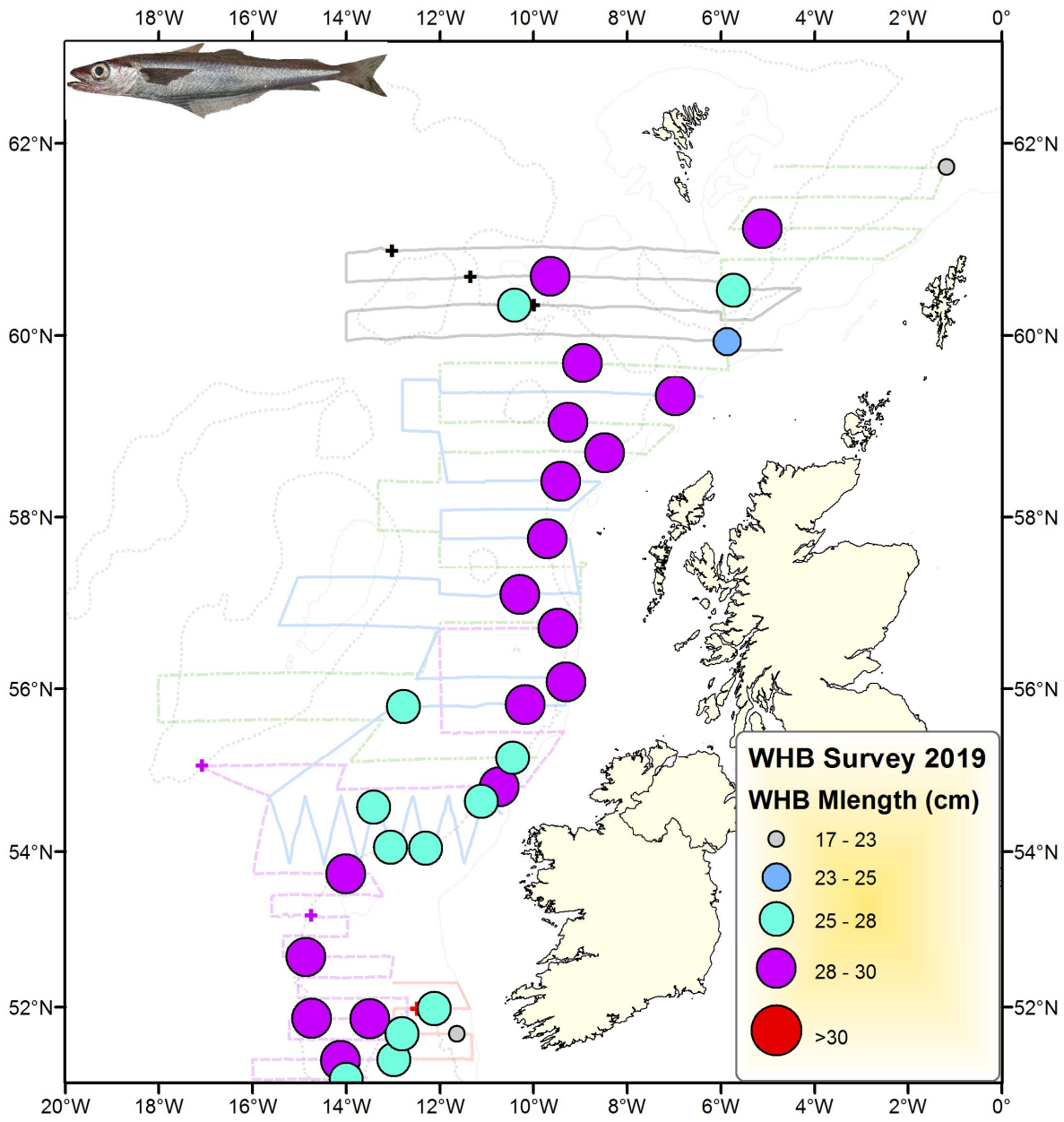


Figure 9. Combined mean length of blue whiting from trawl catches by vessel, IBWSS in March- April 2019. Crosses indicate hauls with zero blue whiting catches.

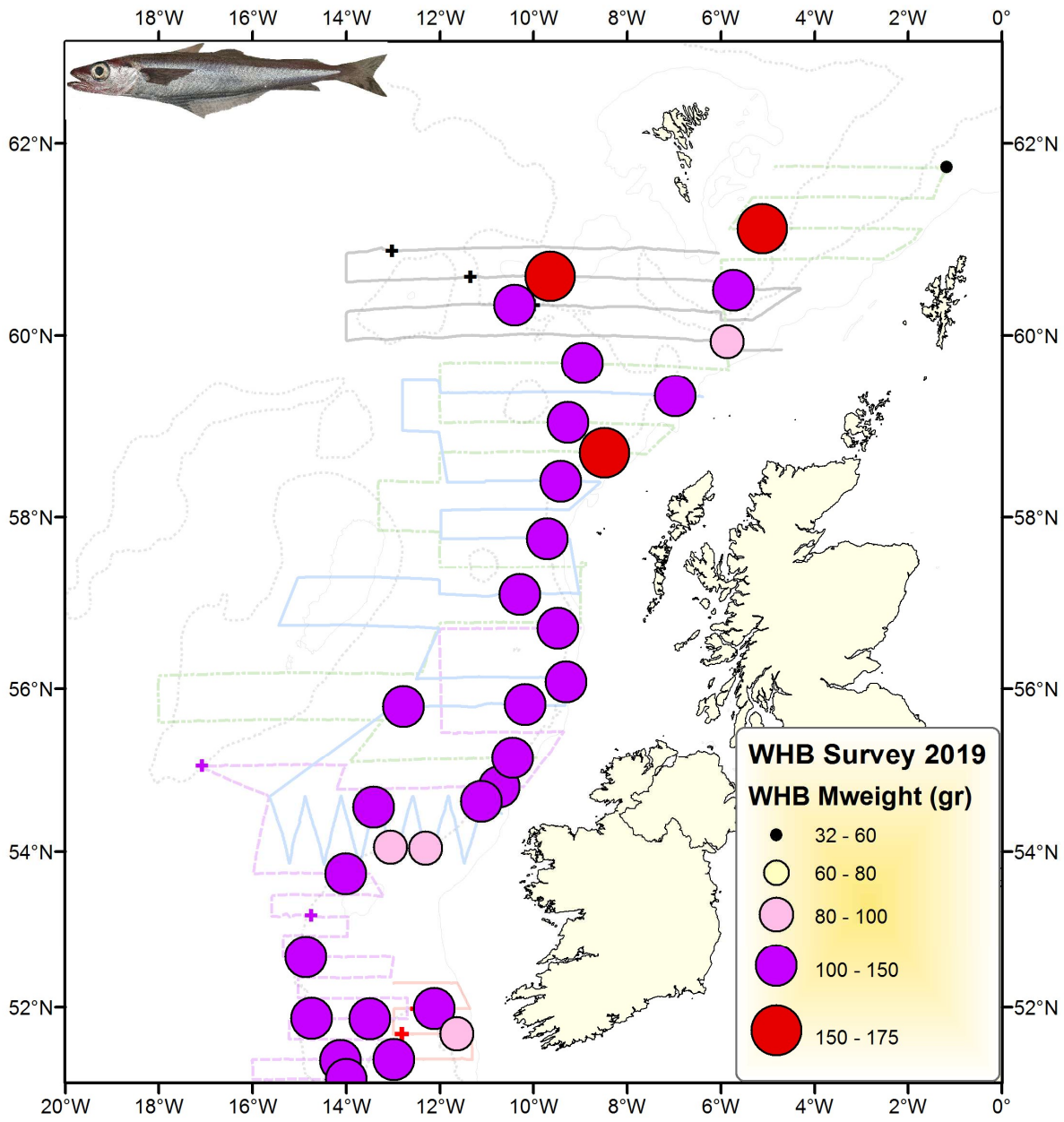


Figure 10. Combined mean weight of blue whiting from trawl catches, IBWSS March- April 2019. Crosses indicate hauls with zero blue whiting catches.

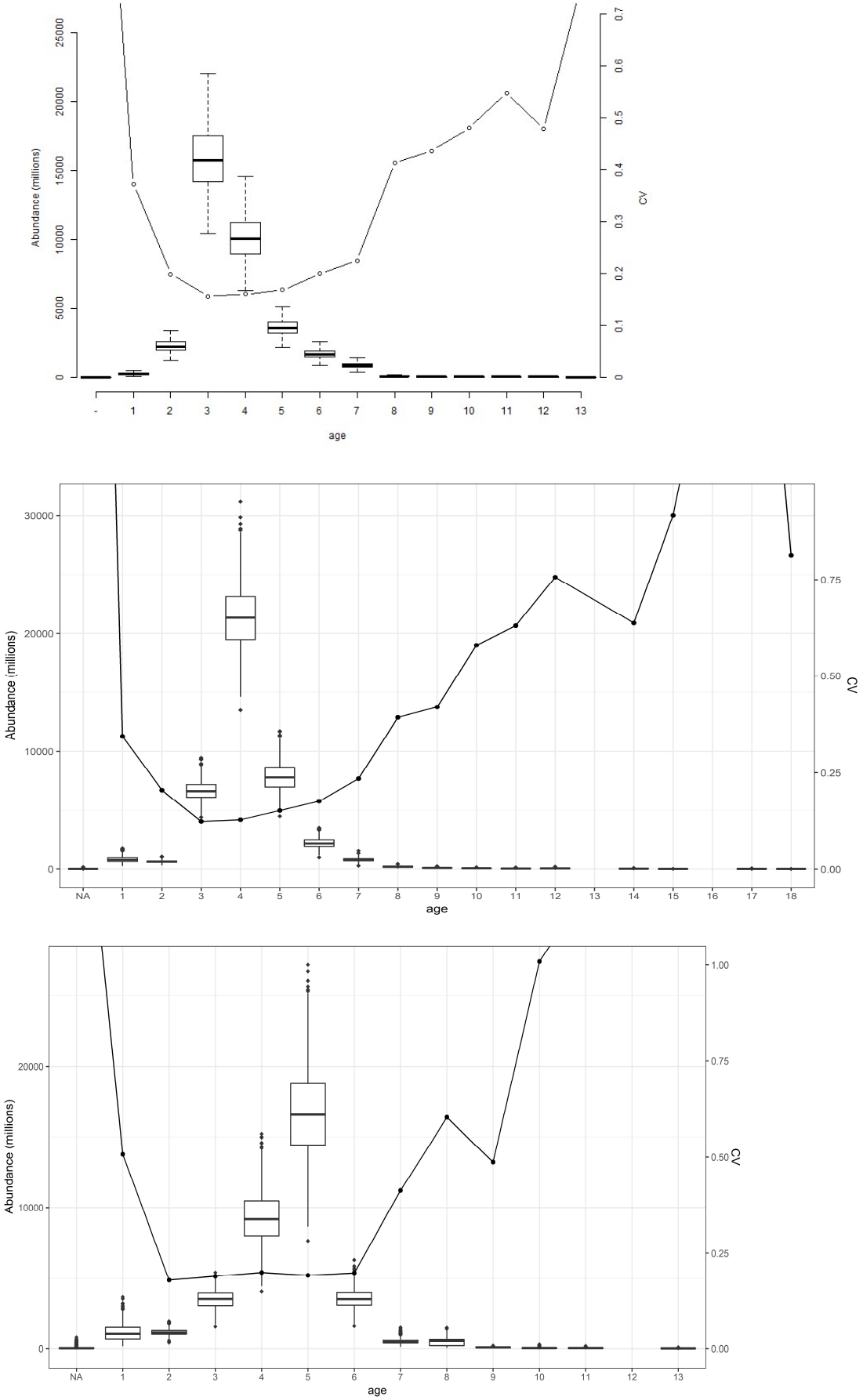


Figure 11. Blue whiting bootstrap abundance (millions) by age (left axis) and associated CVs (right axis) in 2017 (top panel), 2018 (middle panel) and 2019 (lower panel). From StoX.

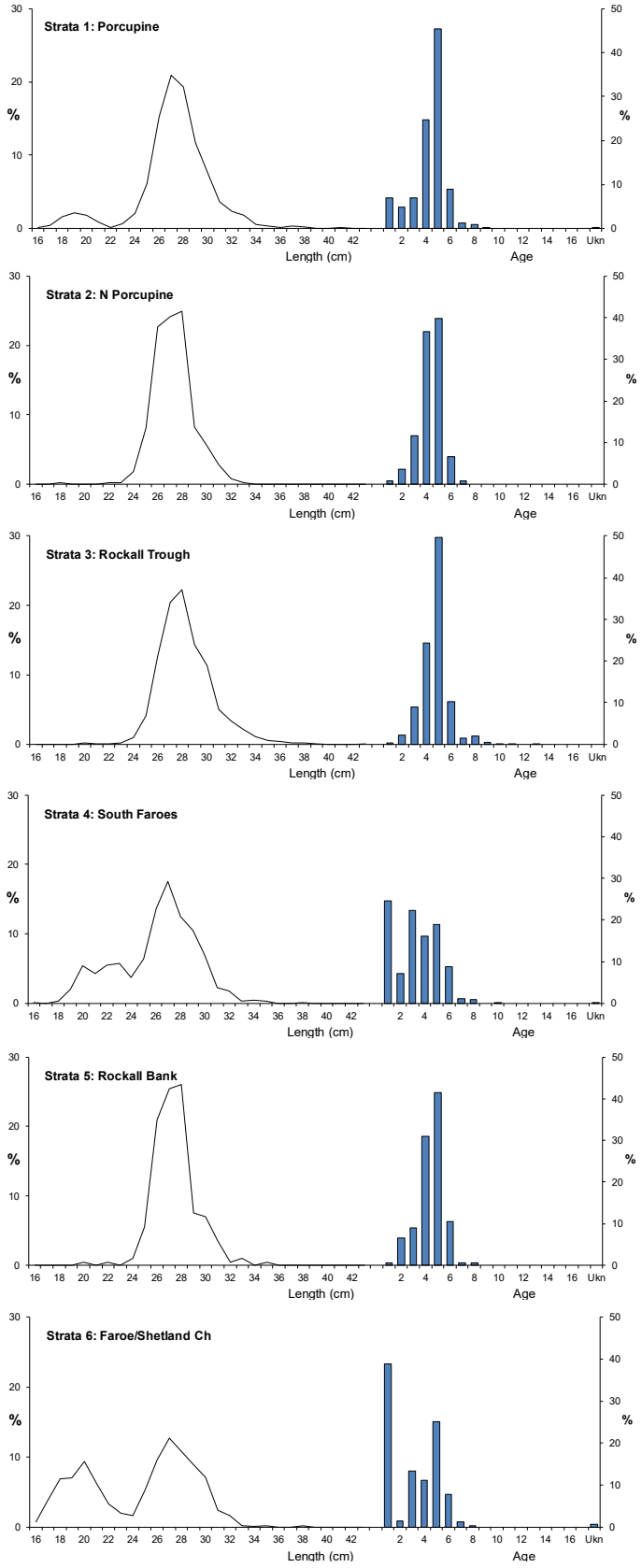


Figure 12. Length and age distribution (numbers) of blue whiting by survey strata. March-April 2019.

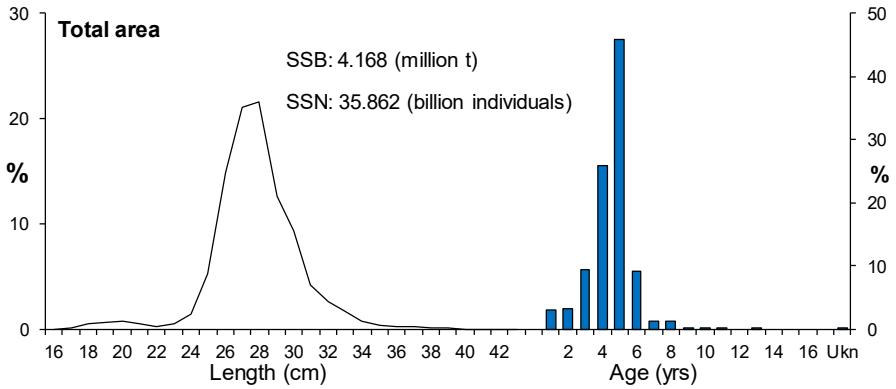


Figure 13. Length and age distribution (numbers) of total stock of blue whiting. March-April 2019.

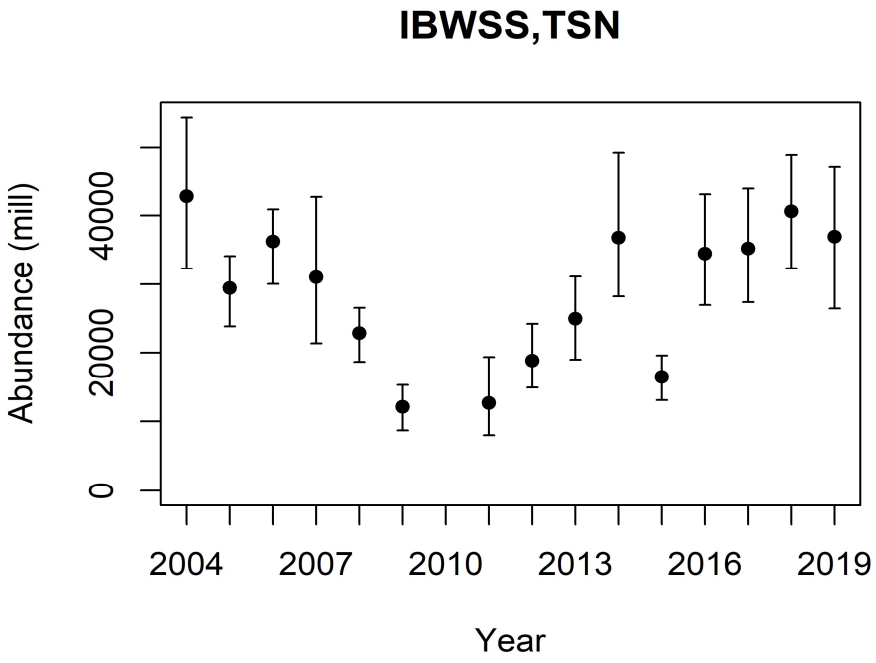


Figure 14. Time series of StoX survey indices of blue whiting abundance, 2004-2019, excluding 2010 due to data problems.

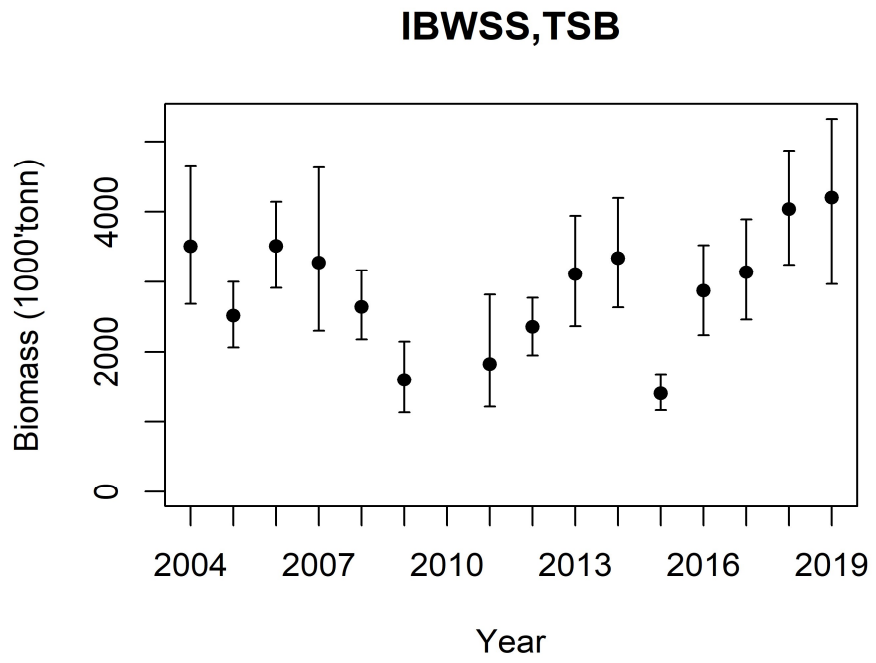


Figure 15. Time series of StoX survey indices of blue whiting biomass, 2004-2019, excluding 2010 due to data problems.

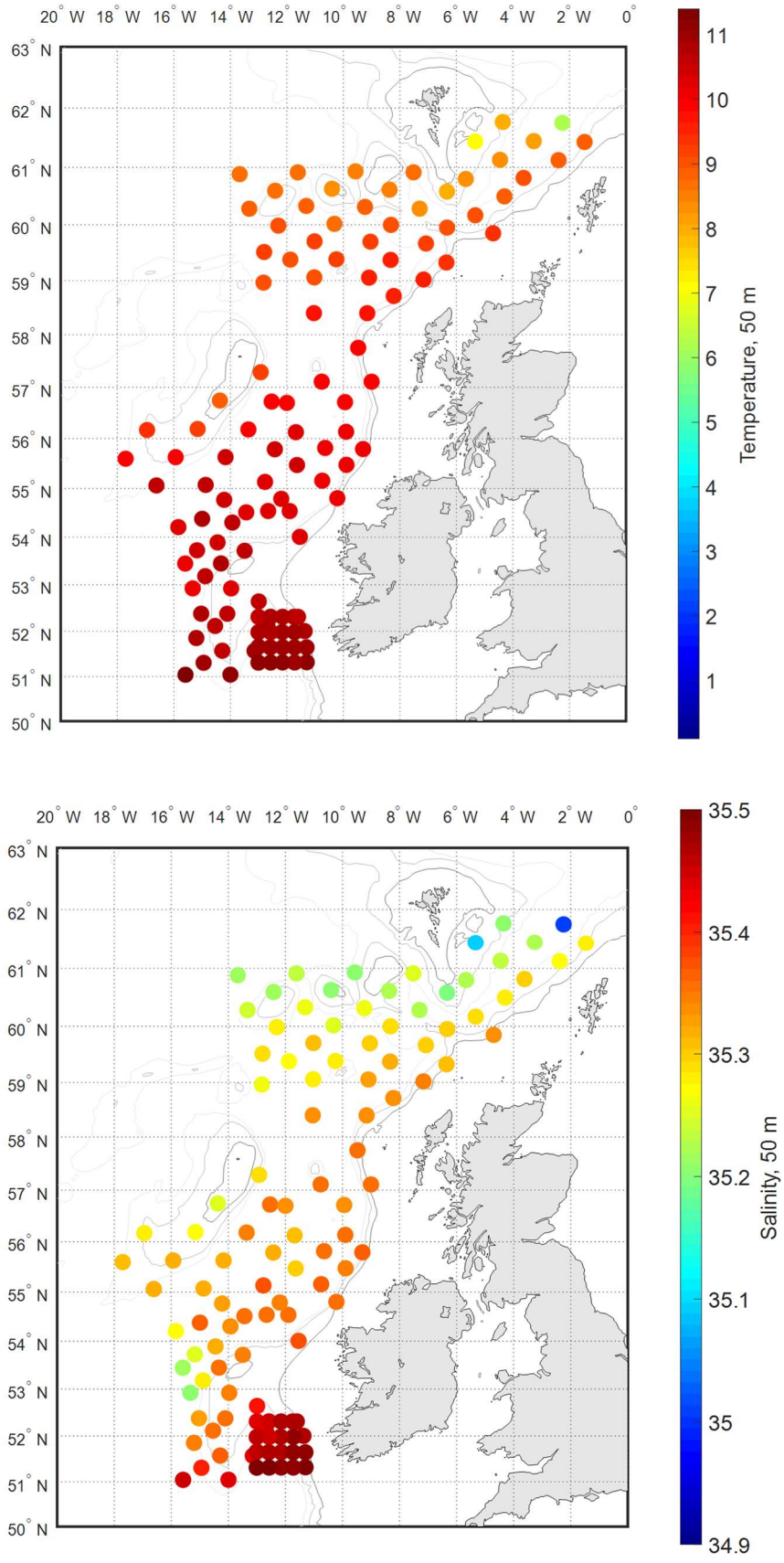


Figure 16. Horizontal temperature (top panel) and salinity (bottom panel) at 50 m subsurface as derived from vertical CTD casts. IBWSS March-April 2019.

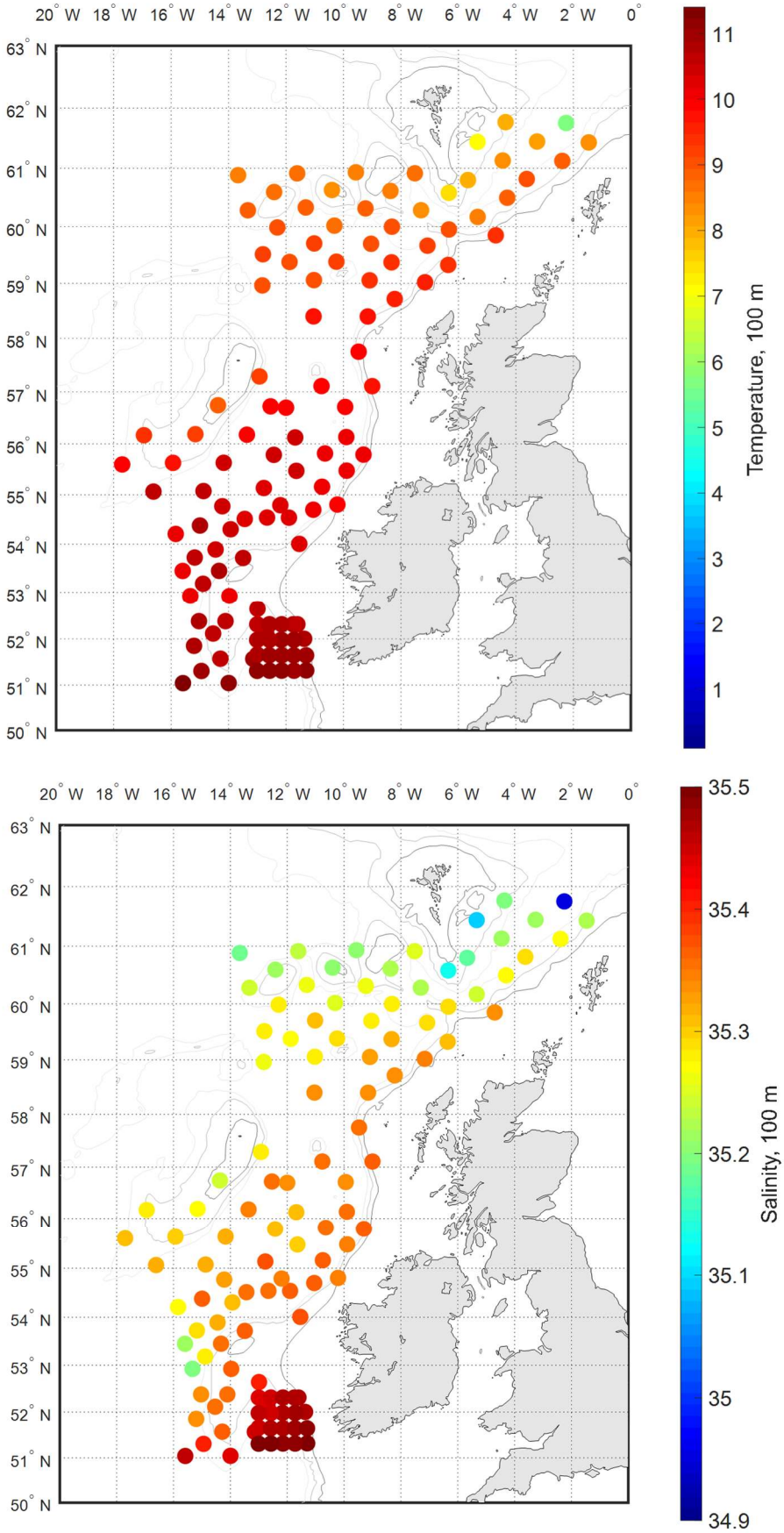


Figure 17. Horizontal temperature (top panel) and salinity (bottom panel) at 100 m subsurface as derived from vertical CTD casts. IBWSS March-April 2019.

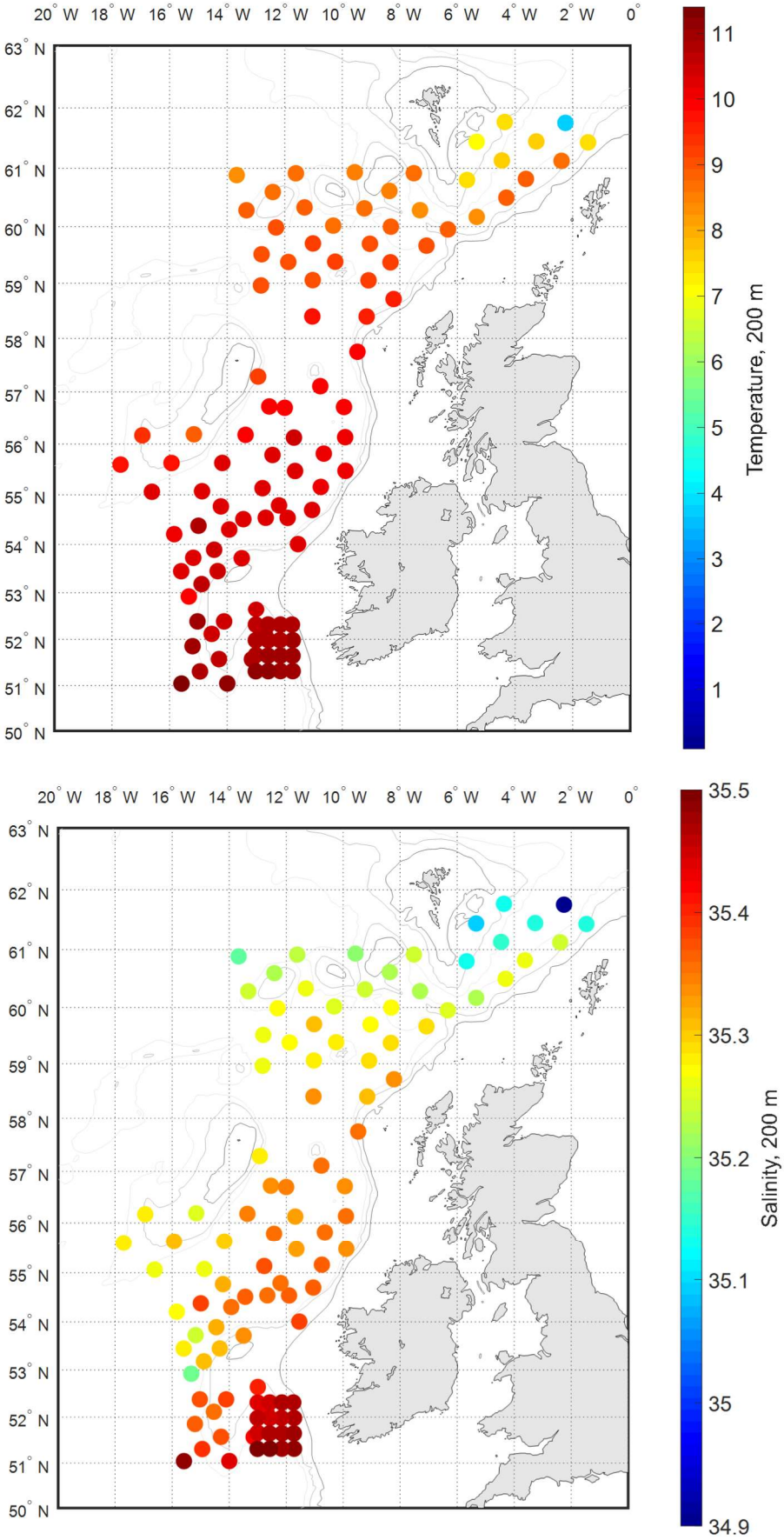


Figure 18. Horizontal temperature (top panel) and salinity (bottom panel) at 200 m subsurface as derived from vertical CTD casts. IBWSS March-April 2019.

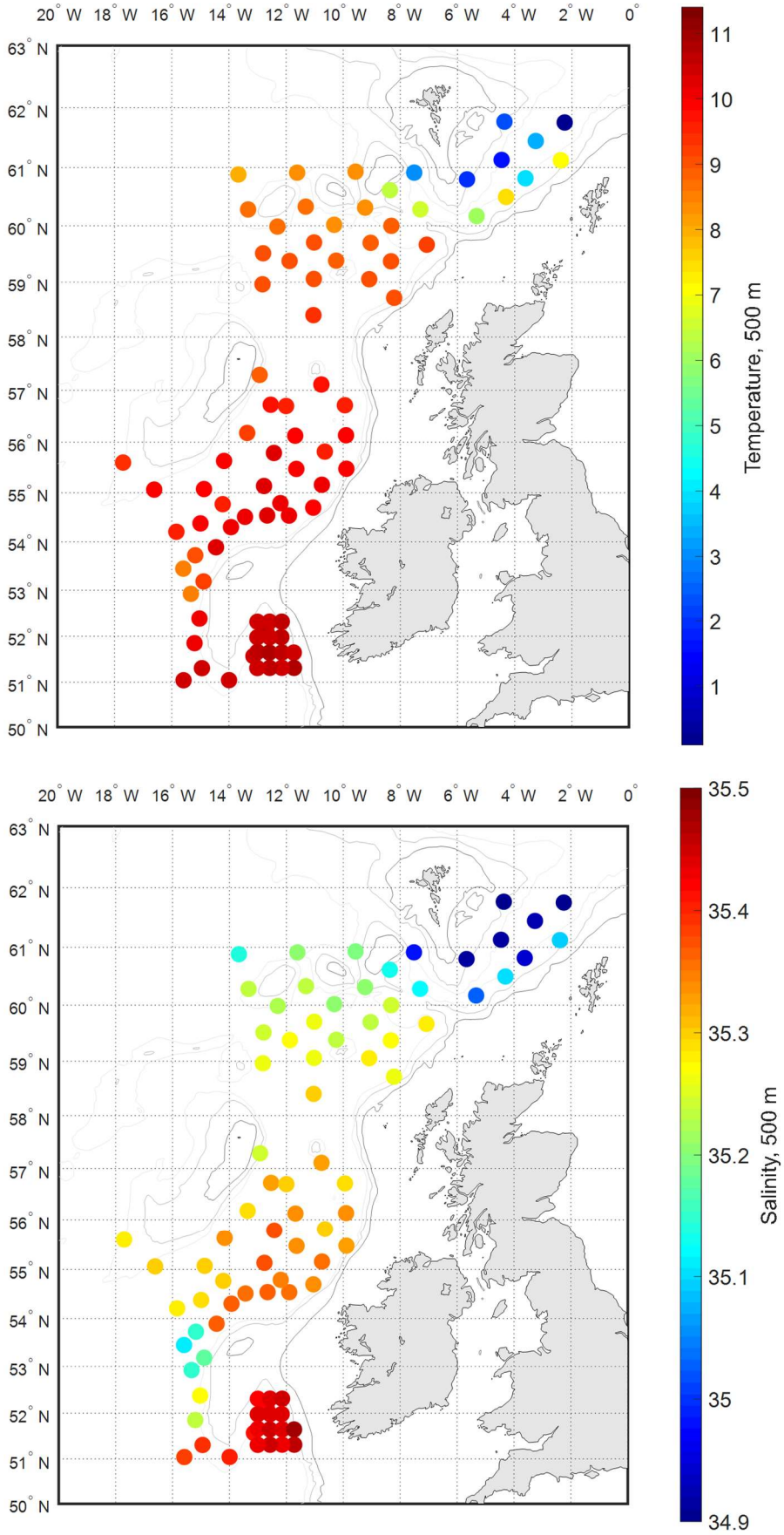


Figure 19. Horizontal temperature (top panel) and salinity (bottom panel) at 500 m subsurface as derived from vertical CTD casts. IBWSS March-April 2019.